Better Hemodynamics and Less Antihypertensive Medication: Comparison of Scalp Block and Local Infiltration Anesthesia for Skull-Pin Placement in Awake Deep Brain Stimulation Surgery

Krauss, Philipp ; Marahori, Natalia Athanasia ; Oertel, Markus Florian ; Barth, Florian ; Stieglitz, Lennart Henning

Abstract: OBJECTIVE In deep brain stimulation (DBS) surgery, acute high blood pressure (BP) is a risk factor for intracranial hemorrhage. To minimize pain and hypertensive conditions, sufficient local anesthesia is mandatory. We evaluated whether local instillation of anesthetics (LA) or a scalp block (SB) is superior concerning intraoperative hemodynamics and analgesia. METHODS We retrospectively analyzed intraoperative cardiovascular parameters and perioperative medication in 47 patients (LA = 29, SB = 18) undergoing DBS surgery. Primary study end points were intraoperative systolic BP and heart rate. Secondary end points were use of intraoperative antihypertensives and perioperative analgesics. RESULTS Patients who had SB showed lower mean systolic BP and heart rate compared with patients who had LA. Patients who had LA required more antihypertensive medication to stabilize BP. BP was higher, particularly during the first 90 minutes of surgery, in patients who had LA. Thereafter, more antihypertensives were necessary to achieve sufficient BP control in the LA group. The dose of analgesics did not differ significantly between both groups during and after surgery. CONCLUSIONS Our data suggest that SB might be superior to LA for DBS surgery with respect to BP control and hemodynamics. The need for analgesics does not differ substantially between both anesthetic treatment options.

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Abstract: Objective: In deep brain stimulation (DBS) surgery, acute high blood pressure (BP) is a risk factor for intracranial hemorrhage (ICH). To minimize pain and hypertensive conditions, sufficient local anesthesia is mandatory. We evaluated whether local instillation of anesthetics (LA) or a scalp block (SB) is superior concerning intraoperative hemodynamics and analgesia.
Methods: We retrospectively analyzed intraoperative cardiovascular parameters and perioperative medication of 47 patients (LA = 29, SB = 18) undergoing DBS surgery. Primary study endpoints were intraoperative systolic BP and heart rate (HR). Secondary endpoints were use of intraoperative antihypertensives and perioperative analgesics.
Results: SB patients showed lower mean systolic BP and HR compared to LA patients. LA patients required more antihypertensive medication to stabilize BP. BP was higher particularly during the first 90 minutes of surgery in LA patients. Thereafter, more antihypertensives were necessary to achieve sufficient BP control in the LA group. The dose of analgesics did not differ significantly between both groups during and after surgery.
Conclusion: Our data suggest that SB might be superior to LA for DBS surgery with respect to BP control and hemodynamics. The need for analgesics differ not substantially between both anesthetic treatment options.

*Title Page

TITLE PAGE

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Better hemodynamics and less antihypertensive medication: Comparison of scalp block and local infiltration anesthesia for skull-pin placement in deep brain stimulation surgery.

Short title:

SB or LA for risk reduction in awake DBS?

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All authors confirm that the manuscript and the order of listed authors has been read and approved by all named authors. L.H.S., M.F.O., F.B. and P.K. devised, initiated and supervised the study. L.H.S., M.F.O, F.B., N.A.M. and P.K. collected all data. P.K. and N.A.M. analyzed and designed corresponding figures and tables. L.H.S., M.F.O. and P.K. performed the surgeries. P.K. and N.A.M. wrote the manuscript with input from all authors.

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Abbreviations: BP = blood pressure, CT = computed tomography, DBS = deep brain stimulation, DPS = definite stimulation point, ET = essential tremor, GA = general anesthesia, HR = heart rate, ICH = intracranial hemorrhage, IPG = impulse generator, i.v. = intravenous, LA = local anesthesia, OR = operation room, PD = Parkinson's disease, SD = standard deviation, SB = scalp block, SEM = standard error of the mean

HIGHLIGHTS:

- **Optimal cardiovascular parameters are known to reduce surgery related risks in DBS.**
- **Scalp block is superior to local anesthesia in providing optimal hemodynamics.**
- **Scalp block patients need significantly less antihypertensives during surgery.**
- **A simple and practical way to optimize DBS surgery**

INTRODUCTION

Deep brain stimulation (DBS) has become a major technique for treating various neurological and psychiatric disorders such as Parkinson's disease, essential tremor, dystonia, obsessive-compulsive disorder or depression, to name but a few indications.[26] Despite its widespread use, surgical techniques differ widely and most centers rely on intraoperative microelectrode recording and macrostimulation to refine electrode placement in the awake patient. During awake surgery, patient comfort might be restricted due to prolonged operating time, pain and withholding of prior medication, thereby triggering increased stress and elevated blood pressure (BP). As high BP is a strong risk factors for intracranial hemorrhage (ICH) in DBS surgery, reducing BP and pain is of utmost importance.[40] In this retrospective analysis of prospectively acquired data we investigate two different methods of local anesthesia for awake DBS and their influence on BP, heart rate (HR) and the use of perioperative antihypertensive medication. Furthermore, we compare the need for analgesics during surgery and the immediate postoperative period in both groups.

METHODS

Ethics approval

The study protocol was approved by the local ethics committee (KEK: *ID 2017-00440*, version 1.2). All patients gave their written consent to participation in the study.

Patients

Electronic data files of all adult patients who underwent stereotactic lead placement for DBS between February 2015 and May 2017 were screened. Age younger than 18 years, patients that received lead placement under general anesthesia (GA) or conscious sedation (defined as having received either dexmedetomidine, propofol or benzodiazepines) were excluded. Intraoperative systolic BP (mean, peaks ≥ 160 mmHg) and mean HR values were defined as primary endpoints of the study. Intraoperative use of cardiovascular or analgesic medication, perioperative occurrence of ICH as seen in the postoperative control computed tomography (CT) scan, and doses of analgesics 24 h after frame fixation were defined as secondary endpoints. Patient characteristics such as sex, age, primary neurological disorder and known arterial hypertension were recorded. No patient was diagnosed with coagulopathy or under the influence of anticoagulant or anti-platelet drugs.

Anesthetic procedure

During the study period, a change of the in-house anesthesia protocol occurred. Before this time point every patient underwent local infiltration anesthesia (LA) at pin insertion and incision sites. After the change, every patient received a scalp block (SB). No further patient selection for the mode of anesthesia was performed. Between frame placement and end of surgery, continuous intra-arterial BP, HR and 3-channel electrocardiography monitoring were routinely performed. Intravenous (i.v.) urapidil (Ebrantil®, Takeda, Opfikon, Switzerland) was administered to prevent systolic BP pressure levels exceeding 160 mmHg. Remifentanil (Ultiva®, GSK, Brentford, UK) was added i.v. whenever patients complained of periprocedural pain. Despite the form anesthesia all further periprocedural interventions were equal.

Scalp block

SB was performed by an experienced neuroanesthesiologist (FB) before frame fixation according to a defined standard operating procedure protocol. In brief, bilateral supraorbital, auriculo-temporal and major and minor occipital nerve areas were targeted with a 23 gauge (G) needle under sterile conditions and continuous monitoring of vital signs. Ropivacaine 0.75% with epinephrine 1:200.000 (5µg/ml) (Naropin®, AstraZeneca, Cambridge, UK) was slowly injected into the subgaleal space with a dose of 1.5 - 2 ml, 3 - 5 ml, 5 ml and 4 ml, respectively.[14] Exclusively during instillation of ropivacaine and not during surgery, a mild sedation with dexmedetomidine (Dexdor®, Orion Pharma, Zug, Switzerland) was performed in few cases. No further application of local anesthesteics at the incision site was performed.

Local infiltration anesthesia

LA was performed by experienced functional neurosurgeons (LS, MO, PK) prior to frame placement. At the four pin insertion sites 3 ml of lidocaine 1 % (formula hospitalis, University of Zurich, Switzerland) and Bupivacaine 0.5% (Carbostesin®, AstraZeneca, Cambridge, UK) (1:1) were administered via a 23 G needle under sterile conditions. After transfer to the operation room (OR), disinfection and sterile draping, the incision sites were similarly instilled with 3 - 5 ml at 3 - 4 min before incision.

Surgical procedure

All surgical interventions were performed by experienced functional neurosurgeons (LS, MO, PK). After instillation of either LA or SB, a Riechert-Mundinger stereotactic frame (Inomed, Emmendingen, Germany) was mounted on the patients' skull via four transcutaneous pin fixations (two frontal and occipital, respectively). Following stereotactic CT scan with contrast agent the patients were transferred to the OR. Direct targeting was performed using the FrameLink™ planning system (Medtronic, Minneapolis, Minnesota, USA). DBS implantation was carried out by a frame-mounted drill (Precisis AG, Heidelberg, Germany) burr hole trepanation. Brain penetration was exclusively performed at systolic BP values under 160 mmHg. An experienced neurologist conducted the intraoperative neurophysiological and clinical assessment. After final lead placement, an immediate postoperative native stereotactic CT was performed to verify the definite lead location and to exclude potential ICH. The implanted programmable generator (IPG) (Activa PC™, Medtronic, Minneapolis, Minnesota, USA) was implanted under GA either subsequently or during a second surgery after three days.

Pin placement for stereotactic frame fixation was defined as the start of the surgery (time point 0).

Statistics

Statistical analysis was performed using the software SPSS Statistics™ (version 24, IBM Corp, Armonk, New York, USA). Datasets were tested for normal distribution with the Kolmogorov-Smirnov normality test. For normally distributed data, an unpaired 2-tailed student's *t* test was used to compare significance of means between two groups. In non-normally distributed data, an unpaired Mann Whitney test was used to compare two samples. Data in text and graphs are shown as mean ± standard error of the mean (SEM). A p value $\leq .05$ was considered significant and indicated by "*", p values $\leq .01$ were indicated by "**", and values $\leq .001$ by "***".

RESULTS

Between February 2015 and May 2017, 69 patients underwent DBS surgery at our department. Of those, 47 patients matched the inclusion criteria and were further analyzed. 29 patients received LA at pin and incision sites, 18 received a SB. Patient demographic data are shown in Table 1. Mean surgery duration was 230.0 ± 4.6 min (LA 237.4 ± 5.6 min vs SB 219.2 ± 7.2 min).

LA patients showed significantly higher mean systolic BP during surgery than SB patients (LA 147.9 ± 1.5 mmHg vs SB 141.9 ± 2.6 mmHg; 2-tailed students t-test: $p = .04$; 95%-CI: [-11.6; -0.4]; r = .31) (Fig. 1). Systolic BP peaks ≥ 160 mmHg were present more often in LA patients (LA 21.1 ± 4.1% vs SB 11.9 ± 3.6%; Mann-Whitney-U test: $p = .11$; r = .23) (Fig. 2) compared to the SB group but without reaching a statistical significant difference. The mean HR during surgery showed was significantly lower in the SB group compared to the LA group (LA 77.9 ± 2.0 BPM vs SB 69.2 ± 2.8 BPM; 2-tailed students t-test: $p = .01$; 95%-CI: [-15.6; - 1.9]; r = .36) (see supplementary material). To maintain a normotensive state, LA patients required significantly more antihypertensive medication compared to the SB group (LA 23.1 ± 5.8 mg/h urapidil vs SB 3.8 ± 1.2 mg/h urapidil; Mann-Whitney-U test: $p < .001$; r = .51) (Fig. 3).

Regarding the time course of surgery, mean systolic BP was significantly higher during minutes 40-80 with similar mean values during the following course of surgery (Fig. 4). During this time period, relatively more patients were in hypertensive state with BP ≥ 160 mmHg (Fig. 5). The mean need for antihypertensives was significantly higher during most of surgery time points from minute 40 on (Fig. 6). For time course details see supplementary material.

Regarding analgesic medication, intraoperative doses of remifentanil, paracetamol (Perfalgan®, UPSA, Rueil Malmaison, France) and metamizole (Novaminsulfon, Sintetica, Mendrisio, Switzerland) showed no significant difference between the two groups (Table 2).

During the postoperative course, doses of analgesics including paracetamol, metamizole and morphine (Sintetica, Mendrisio, Switzerland) showed no significant difference between LA and SB groups (Table 2).

In 32 patients (LA n = 22, SB n = 10), implantation of the IPG was performed directly after lead placement. In this subgroup, SB patients required significantly less remifentanil doses during the second intervention (LA 0.583 ± 0.049 mg/h remifentanil vs SB 0.223 ± 0.044 mg/h remifentanil; Mann-Whitney-U test: $p = .003$; r = .53) (Table 2).

DISCUSSION

In this retrospective analysis of prospectively collected datasets, we compared LA and SB in patients undergoing awake DBS surgery according to BP, HR, intraoperative use of antihypertensive medication and perioperative need of analgesics.

SB for awake procedures in neurosurgery has been shown to be a safe method in both adults[20] and children,[24] although its analgesic effects are still controversially debated.[35] During these special kinds of operations including frame-based stereotactic procedures, pain due to pin placement and skin incision needs to be sufficiently controlled.

In general, stereotactic DBS lead placement is considered a relatively safe technique with bleeding rates usually of only 2 - 4% (range, 0.0% - 34.4%).[2,16] Because of its minimal invasive character, stereotactic procedures are prone for awake surgery in LA, to perform intraoperative neurophysiological target verification and clinical assessment. However, as the target regions are usually located deep in the brain, even a small ICH can be fatal. Different factors have been described to augment the risk of ICH in DBS patients. Microelectrode recordings,[40] multiple brain trajectories[3,8,17,31,40] and patient age[9] as well as high BP[4,33] seem to be major risk factors. Therefore, especially high BP must be meticulously avoided during surgery.

Effect of scalp block on blood pressure and risk of hemorrhage

In patients undergoing craniotomy under GA, it could be demonstrated that SB reduces the rate of arterial high BP or tachycardia in adults and children.[10,14,19,33,38] In a study comparing LA and SB prior to pin placement for craniotomy under GA, SB was shown to significantly lower BP and HR when compared to saline or LA during and immediately after pin placement but not during the further course of surgery.[6,12,18,23,28,32] Furthermore, it was shown that BP and HR were significantly more stable during stereotactic procedures with SB than under conscious sedation alone.[13]

In our study, patients receiving SB showed a significantly lower mean BP, significantly lower HR and less hypertensive peaks during surgery as expected. Even though an averaged difference of 6 mmHg over the whole surgery rmay seem small, this effect became more prominent during the first 90 min of surgery, which usually includes lead placement. Patients in the SB group required significantly less antihypertensive medication with an overall more stable BP profile over time. This phenomenon could also be found comparing SB and LA or saline for craniotomy under GA.[21] In another study, patients without SB needed significantly deeper anesthesia to maintain normal BP and HR during craniotomy under GA.[6] Both a single asymptomatic cortical ICH and a symptomatic ICH of the internal capsule occurred in the LA group in the present series. The patient with capsular ICH became symptomatic during surgery, whereas the cortical ICH was an incidental finding in the postoperative CT scan. The associated transient paresis of the right lower limb improved significantly within the first four months postoperatively. Interestingly, the patient suffering from capsular ICH had a known history of art. hypertension high systolic BP and a higher than average antihypertensives dose during surgery. However, as bleeding rates are typically low, direct conclusions on safety cannot be drawn from our cohort due to the relatively small sample size.

Effect of scalp block on patient comfort

Awake DBS can be a stressful experience for patients deprived from their disease specific medication or suffering from insufficient analgesia. Patient discomfort and pain are known to raise BP and HR.[34] Therefore, it might indirectly increase the risk of ICH. On the other hand, BP and HR can be analyzed as surrogate parameters for patient discomfort during surgery. Pain control is usually established by applying i.v. sedative and pain medication (mainly propofol, fentanyl, remifentanil, or dexmedetomidine) with or without local anesthesia. Generally, local anesthesia can be either performed as LA at pin and incision sites or as SB.[11,25,30,36] In a cohort undergoing radiosurgery, supplementing local anesthesia at the pin sites with SB reduced head pain better than LA alone.[7,15] The procedure of SB itself was shown to be less painful than LA at pin sites, however no significant difference of pain during pin placement was present.[27] Another study showed that a group receiving a combination of SB with psychological guidance required less propofol and remifentanil than a group treated with LA and sedation during DBS surgery.[37] Pain rates during the early postoperative phase[22] and the first 24 h[1,5,6] after craniotomy under GA were reduced when SB was applied before surgery. The need for analgesics was reduced after infratentorial craniotomy[29] but not for supratentorial craniotomy[1] under GA. In our cohort, no differences in the use of analgesics during awake surgery were present. Along with the hemodynamic parameters described above (effect of scalp block on BP and risk of ICH), this may reflect an improved analgesic effect of the SB. During the postoperative period, no differences in the use of the analgesics including opioids were seen. We suppose this could be due to the minimal skin incisions during DBS.

In the subgroup of patients that underwent IPG implantation the same day of initial DBS surgery (LA n = 23, SB n = 11), less opioids were necessary during GA in the SB group compared to the LA group. We recognized a faster recovery in these patients. Still, this rests an unstructured observation, opioid sparing procedures were shown to have beneficial effects on postoperative vomiting and nausea in non-neurosurgical patients.[39]

There are several study limitations and caveats. Apart from its retrospective character, the small sample size and number of DBS procedures decreases the statistical power of our study and decisive conclusions cannot be reached. As PD in later stages in known to affect vegetative functions, s.a. BP, the slightly higher proportion of PD patients in the LA group may contribute to less stable hemodynamics in this cohort. Moreover the application of dexmedetomidine in few cases may have interfered with hemodynamics, still, no signs of sedation were apparent during surgery in these patients. Furthermore, a clear limitation is that no structured assessment of pain was performed and the analgesics (paracetamol, metamizole) are usually prescribed on a fixed basis during the immediate postoperative period.

CONCLUSIONS

As most centers rely on microelectrode recording and clinical test stimulation during awake DBS lead implantation, patient comfort as well as pain and BP control have high priority specially to reduce the risk of ICH. We could show that SB provides better hemodynamic control than LA during lead placement at the pin insertion and incision sites. The hemodynamic stability is reflected by the decreased use of urapidil during lead insertion. We therefore conclude that SB might be superior to LA for patient comfort and risk reduction in awake DBS. However, larger prospective randomized and controlled studies are necessary to further assess the impact of SB on BP control and risk of ICH in DBS surgery.

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Table 1: demographic data

	LA	SB
N	29	18
Sex (m : f)	15 : 14	9 : 9
Age (y ± SD)	63.8 ± 9.6	65.2 ± 10.5
Disease (PD : ET)	26 : 3	13 : 5
History of hypertension (n)	6	5

LA = local anesthesia, SB = scalp block, N = number, m = male, f = female, SD = standard deviation, PD = Parkinson`s disease, ET = essential tremor

Table 2
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Table 2: perioperative drug administration

Time Point	Drug	LA	SB	p-value
First intervention				
intra-op	Paracetamol (g/h ± SEM)	0.02 ± 0.02	0.11 ± 0.03	.87
	Metamizole (g/h ± SEM)	0.01 ± 0.02	0.06 ± 0.03	.53
	Remifentanil (mg/h ± SEM)	0.000 ± 0.000	0.040 ± 0.024	.11
24 h post-op	Paracetamol (g/24h ± SEM)	2.48 ± 0.16	1.89 ± 0.28	.09
	Metamizole (g/24h ± SEM)	1.88 ± 0.25	1.22 ± 0.27	.08
	Morphine (mg/24h ± SEM)	0.69 ± 0.48	0.22 ± 0.22	.82
Second intervention	Remifentanil (mg/h ± SEM)	0.583 ± 0.049	0.223 ± 0.044	.003**

LA = local anesthesia, SB = scalp block, SEM = standard error mean

Table supp.

Surgery time (min)	SBP (mmHg; mean ± SEM)			Hypertension (%)		Antihypertensives (mg/h; mean ± SEM)			Group size (n)	
	LA vs SB		p	LA vs SB		LA vs SB		p	LA vs SB	
0	147.0 ± 4.3	136.2 ± 4.6	ns	0.0	5.6	0.0	0.0	ns	4	18
10	151.2 ± 8.2	135.7 ± 3.6	ns	60.0	5.6	0.0	0.0	ns	5	18
20	152.9 ± 6.8	140.9 ± 4.2	ns	55.6	22.2	0.0	0.0	ns	9	18
30	153.1 ± 5.1	143.2 ± 3.7	ns	43.8	16.7	3.1 ± 2.3	0.0	ns	16	18
40	162.4 ± 4.2	141.6 ± 3.8	.001	56.5	22.2	13.1 ± 5.5	0.0	.041	23	18
50	158.7 ± 2.9	143.7 ± 4.6	.006	46.2	16.7	18.3 ± 7.5	5.0 ± 5.0	ns	26	18
60	161.7 ± 3.6	139.1 ± 4.3	.0001	57.1	5.6	23.3 ± 6.0	3.3 ± 2.3	.007	28	18
70	151.9 ± 4.3	137.9 ± 3.3	.024	42.9	5.6	22.1 ± 5.8	6.7 ± 3.9	.014	28	18
80	149.9 ± 2.9	140.1 ± 3.9	.037	24.1	16.7	18.7 ± 5.3	1.7 ± 1.7	.002	29	18
90	150.6 ± 2.8	143.7 ± 4.1	ns	34.5	27.8	26.7 ± 8.0	11.7 ± 7.3	ns	29	18
100	148.6 ± 2.7	141.2 ± 3.2	ns	24.1	5.6	22.8 ± 5.8	11.7 ± 6.0	ns	29	18
110	144.9 ± 1.9	144.6 ± 3.6	ns	10.3	11.1	20.4 ± 6.1	6.7 ± 5.2	.007	29	18
120	144.9 ± 2.0	143.4 ± 3.1	ns	6.9	22.2	24.7 ± 5.2	1.7 ± 1.7	.0001	29	18
130	145.3 ± 2.2	145.1 ± 3.6	ns	13.8	11.1	23.0 ± 6.5	10.0 ± 4.9	.046	29	18
140	145.2 ± 1.7	142.4 ± 2.9	ns	10.3	5.6	15.1 ± 4.3	3.3 ± 2.3	.009	29	18
150	145.9 ± 1.9	141.3 ± 3.0	ns	10.3	5.6	26.3 ± 10.3	3.3 ± 2.3	.007	29	18
160	142.9 ± 1.8	142.3 ± 3.3	ns	3.5	5.6	40.9 ± 16.4	3.3 ± 3.3	.001	29	18
170	144.9 ± 2.6	143.6 ± 3.4	ns	13.8	16.7	48.8 ± 39.2	8.3 ± 5.8	.028	29	18
180	144.8 ± 2.4	142.6 ± 2.9	ns	10.7	17.7	45.2 ± 23.8	5.0 ± 3.6	.005	28	17
190	146.1 ± 2.3	144.5 ± 3.3	ns	22.2	17.7	12.9 ± 4.1	6.7 ± 3.9	ns	27	17
200	144.7 ± 2.2	140.0 ± 3.5	ns	14.8	7.7	22.3 ± 7.1	0.0	.0001	27	13
210	146.2 ± 2.1	142.9 ± 3.7	ns	8.0	8.3	24.4 ± 8.7	0.0	.002	25	12
220	145.6 ± 2.5	143.8 ± 3.6	ns	8.7	0.0	24.8 ± 8.7	0.0	.012	23	10
230	142.4 ± 3.1	145.9 ± 3.1	ns	17.4	0.0	16.1 ± 6.4	0.0	.038	23	7
240	141.3 ± 3.8	142.0 ± 11.1	ns	6.3	0.0	18.7 ± 7.8	0.0	ns	16	3
250	131.9 ± 3.5	134.7 ± 17.6	ns	0.0	0.0	4.9 ± 3.0	0.0	ns	11	3
260	140.5 ± 2.5	144.0 ± 7.8	ns	0.0	0.0	5.3 ± 3.7	0.0	ns	8	3
270	138.7	147.3	ns	0.0	0.0	5.1	0.0	ns	6	3

	± 4.2	± 8.7				± 4.2				
280	139.3 ± 6.9	130.0	ns	0.0	0.0	0.0	0.0	ns	4	1
290	125.0	-	-	0.0	-	0.0	-	-	1	0

SBP = systolic blood pressure, LA = local anesthesia, SB = scalp block, SEM = standard error mean, n = number, ns = non significant

Figure 1
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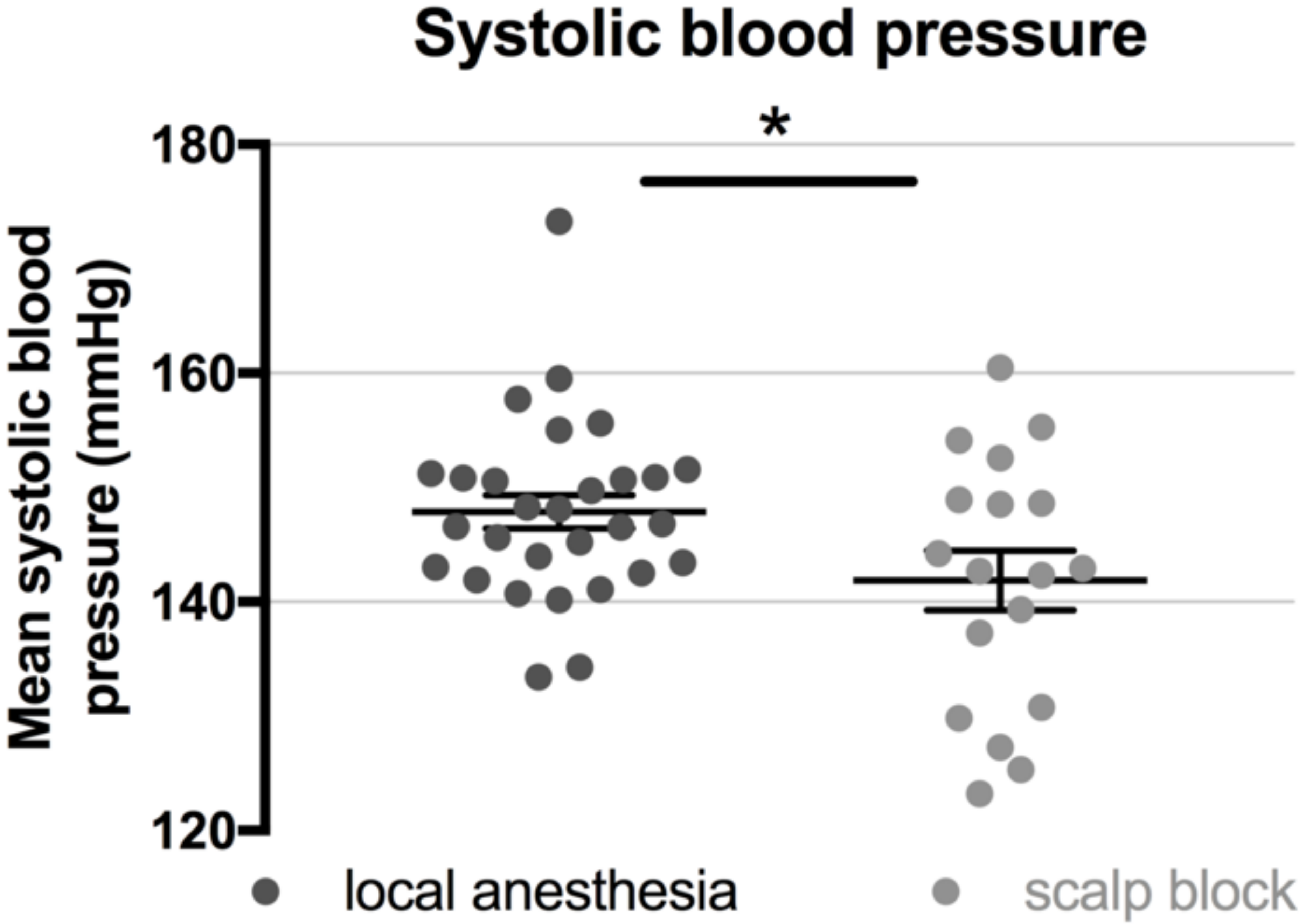

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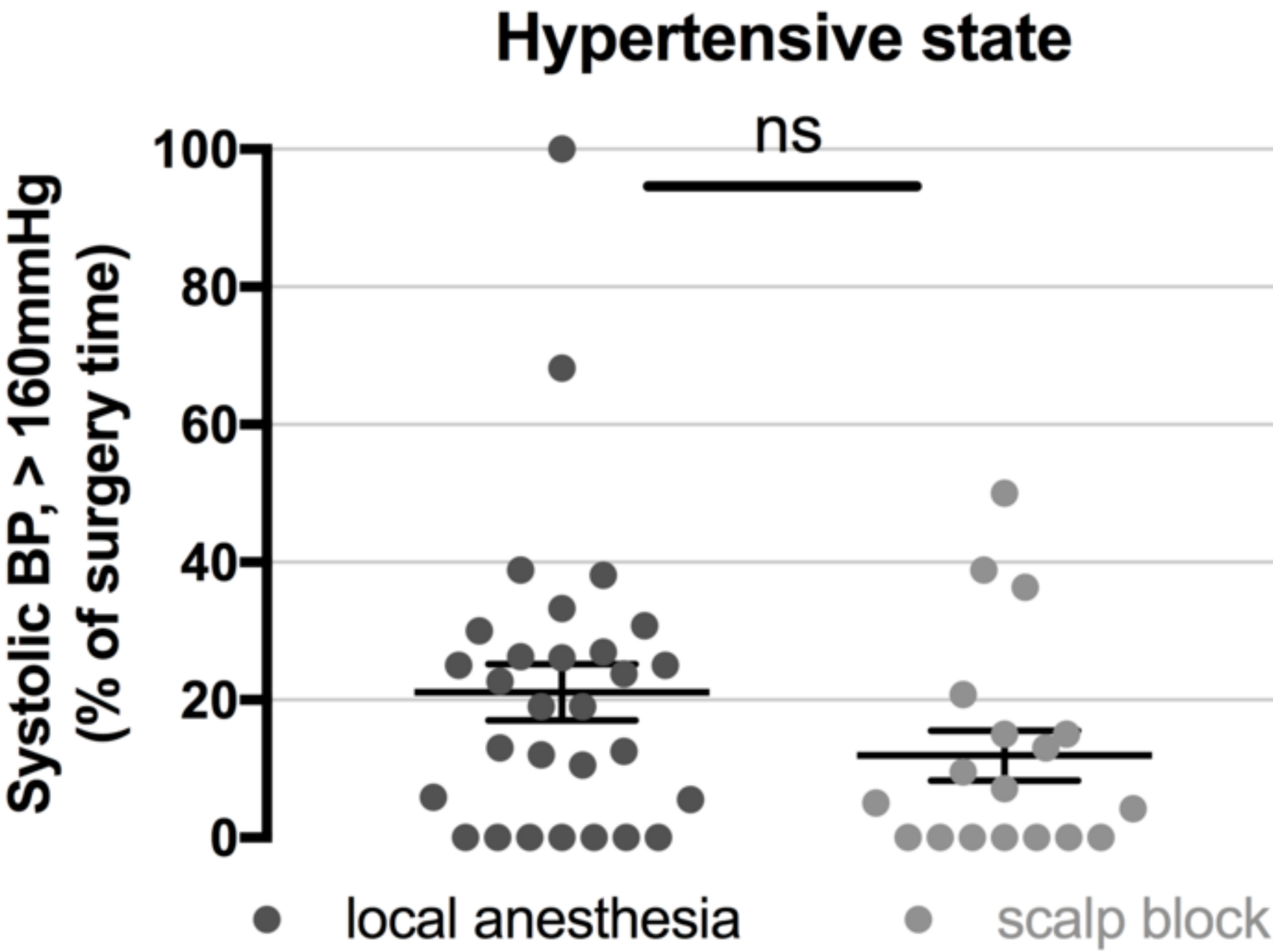

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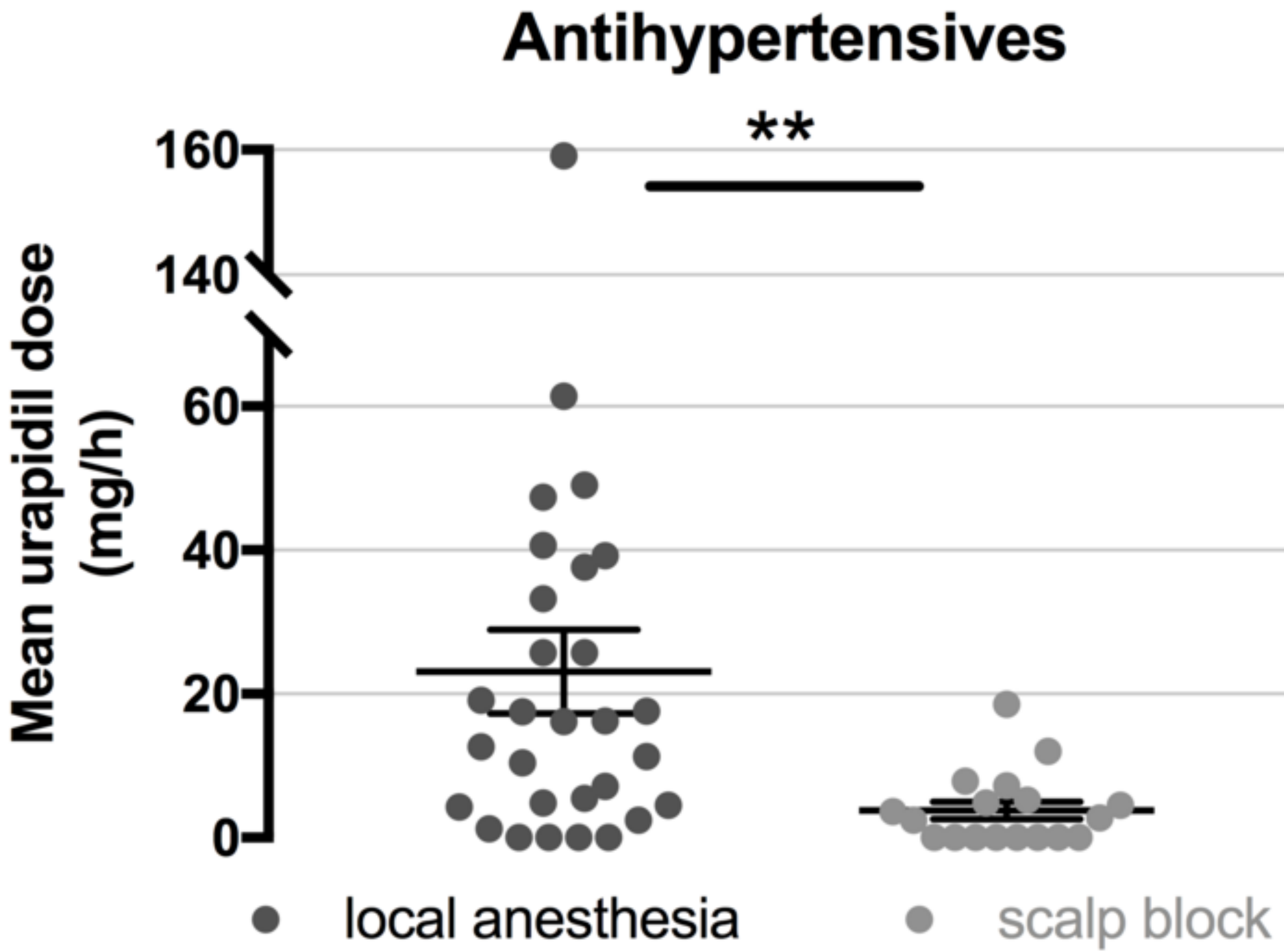

Figure 4

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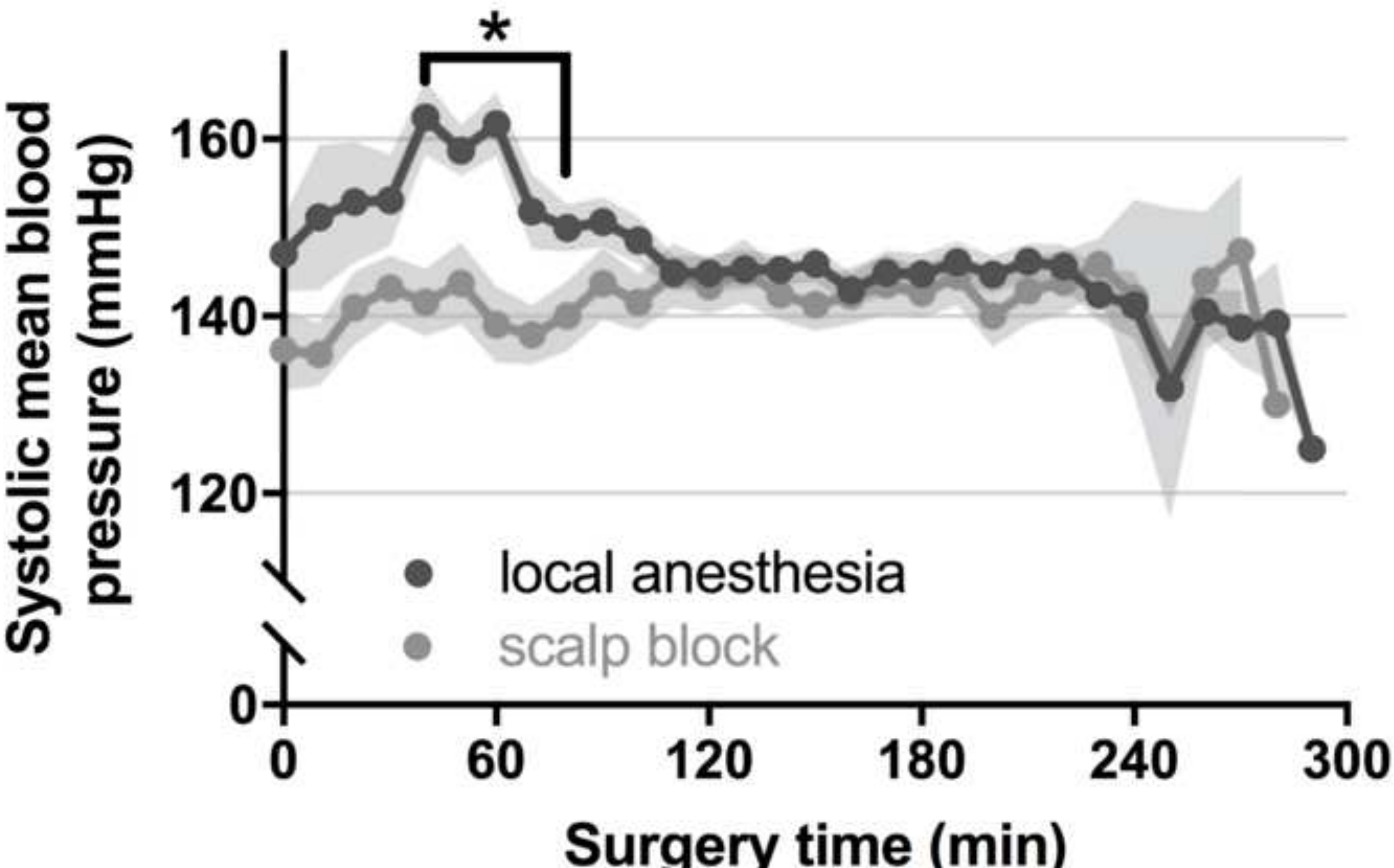

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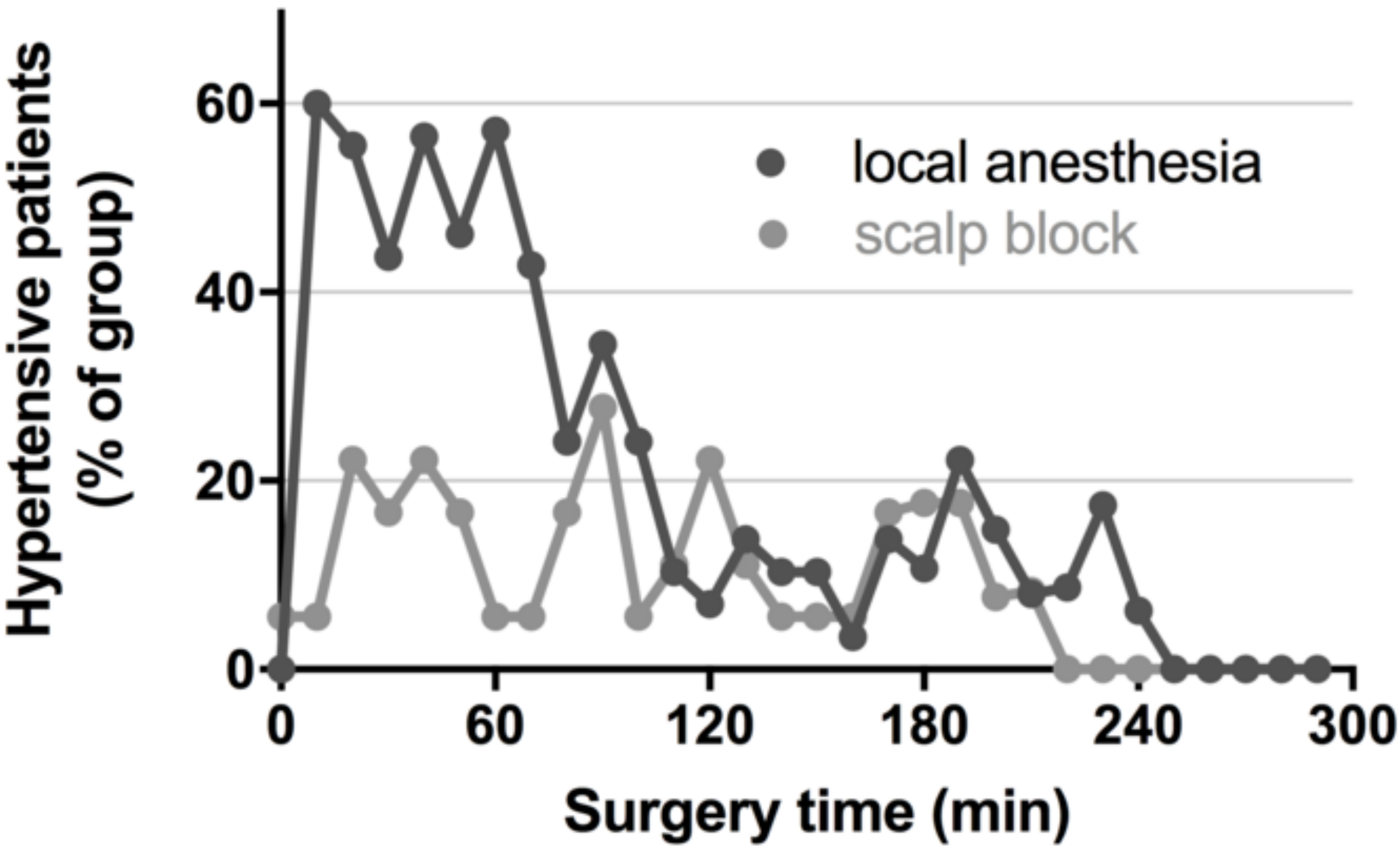

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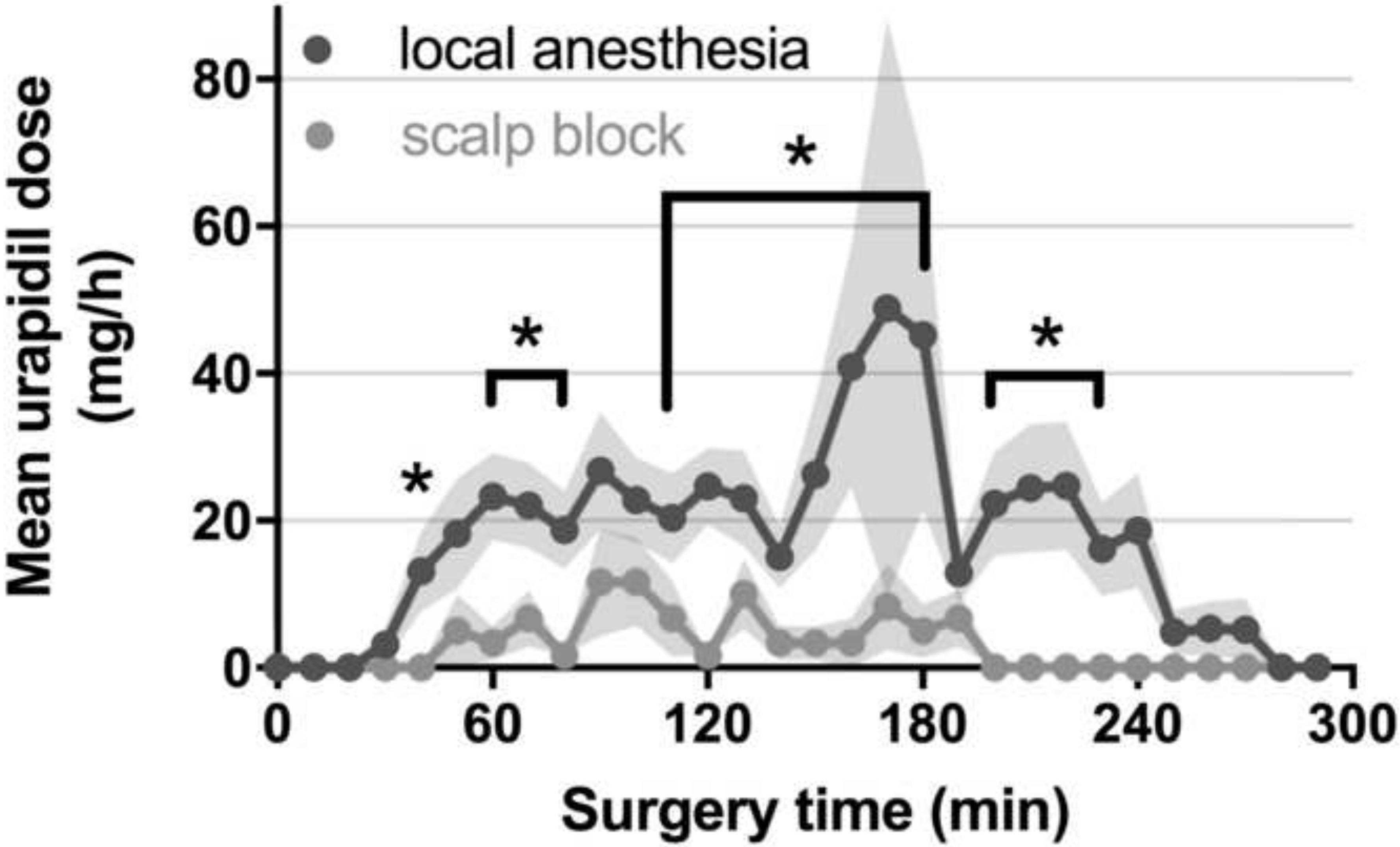

Figure supplementary material

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